Canada Mortgage and Housing Corporation
Société canadienne d'hypothèques et de logement

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ADDITIONAL SOIL GAS SAMPLING PROCEDURES

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May 31, 1988

Final Report No. P.88-5647/FG

Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is reponsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part V of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

This publication is one of the many items of information published by CMHC with the assistance of federal funds.

This study was conducted by Ontario Research Foundation, Buchan, Lawton and Parent Ltd., and Gartner Lee Limited for Canada Mortgage and Housing Corporation under Part V of the National Housing Act. The analysis, interpretations, and recommendations are those of the consultants and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

ACKNOWLEDGEMENTS

The authors would like to thank the homeowners, Mr.T. Hildritch, Mr. Reynolds, Mr. I. Thomson and their families, for permitting the use of their homes and property for this study, and being most hospitable when tests were conducted on their properties.

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for
Canada Mortgage and Housing Corporation
Ottawa, Ontario

SUMMARY

This progress report describes the activities associated with the construction of three types of soil gas sampling equipment and the testing and evaluation of this equipment in three houses. Laboratory and field tests were undertaken as part of the tests and evaluations. At one house, house leakage and infiltration characterization tests were performed for prediction of soil source strength and infiltration rates.

Based on the findings of the previous CMHC study completed in 1987, various soil gas sampling techniques were constructed for further evaluation. Equipment was constructed for the sampling of basement soil gas entry points such as floor drains, sump pits, and floor and wall cracks. For sampling of floor drains and sump pits various sized enclosures were built which could fit over these openings. Attached to the enclosures were straight tubes of set diameter which connected to thin-wall plastic sampling bags. Based on laboratory tests, it was predicted that the differential pressures encountered across floor drains or sump pits would passively inflate the sampling bags.

For sampling of floor and wall cracks, two techniques were

developed for containing soil gases which might enter basements. One technique consisted of an enclosure which would cover the direct area of the crack plus a shroud which would extend beyond the area covered by the enclosure. A sample would then be obtained by actively withdrawing soil gas from the enclosure by means of a pump and a sampling container. A second technique consists of drilling a 13 mm diameter hole through the basement foundation wall and inserting and sealing a sampling tube through the hole. This tube insures that a sample of the soil gas is obtained at the wall-soil interface at the exterior of the foundation and that no short circuiting occurs through the foundation wall. A sample may be obtained either actively or passively from the sampling tube. If a passive sample is to be obtained, then calibrated orifices can be used to determine the natural sampling flow rate over the measurement period.

This report outlines the field testing conducted in three houses; two with concrete block basement construction and one with poured cement basement construction. The floor drain enclosures were placed over floor drains and a sump pit and the passive sampling bag satisfactorily obtained samples in one hour. Pressure differentials of 1 to 2 Pa were measured across the floor drains and sump pit during the tests.

Wall tubes were installed in walls and floors. Again, the passive sampling bag obtained soil gas samples in one hour. A wall crack

enclosure was installed over a wall crack and actively sampled in conjunction with SF_6 tracer injection in the soil immediately adjacent to the house.

In order to evaluate whether the soil gas sample obtained by the sampling techniques is similar to the soil gas in-situ, a tracer gas, SF_6, was injected into the soil adjacent to the house opposite the basement sampling location. The tracer gas was then sampled in the soil near the crack or wall tube entry points and at the interior entry points with the three sampling techniques.

The floor drain and sump pit enclosure sampling techniques were successfully used to obtain soil gas samples of 10 L in time periods of one hour or less. The wall tube sampling technique, when used in conjunction with the passive bag or with a sampling pump, was also successful. The rate at which the samples were collected in the passive bags can be used to determine the rate of entry of soil gas. The designs were such that they could be constructed at low cost.

Conclusive results were not obtained to determine that the wall crack enclosure technique was successful in obtaining an undiluted soil gas sample. It is recommended that this technique is not used in block wall construction due to potential dilution from the block voids.

1. INTRODUCTION

The leakage of air into basements below grade is a potential source of indoor contaminants including radon, pesticides, sewer gases, petroleum product fumes from spills, moulds and moisture. Soil gas enters through unintentional cracks, joints and openings in foundation walls and floors and through intentional openings such as floor drains and sump pits. In order to characterize the soil gas pollutant source, Canada Mortgage and Housing Corporation (CMHC) propose to conduct a survey of Canadian housing. The characterization of soil gas requires the development of a sampling technique which conveniently and accurately determines the quality and emission strength of soil gas which enters into residential basements.

This study is the second phase of a program for CMHC to develop a soil gas sampling technique. In the first phase, three techniques were evaluated. The enclosure of entry points and the measurement of contaminants with passive diffusion samplers for volatile organics was not successful because of the high moisture levels and low air velocities present in the sampling enclosures. The high moisture levels could have severely limited the adsorption capacity of the samplers and an airflow velocity below the minimum face velocity required for diffusion monitors could have starved the monitors.

The installation of soil probes in the ground adjacent to the building foundation above the water table and the subsequent active sampling from these probes was successful. However, passive diffusion sampling for volatile organics was not successful in these probes for the same reasons as for the entry point containers. The cost of manufacturing and installing these probes limits their use to specific studies and excludes them from application to large field surveys.

The enclosure of entry points and the measurement of contaminants with active sampling was considered promising. Equipment was easily assembled and on-site procedures were simple and convenient. Samples of sufficient size for analysis were obtained. However, it was not known whether the sample obtained was representative of actual soil gas. In addition, the technique did not determine the rate of entry of soil gas.

For this second phase of the project, Ontario Research Foundation (ORF) in conjunction with Buchan, Lawton, Parent Ltd. (BLP) and Gartner Lee Ltd (GLL) developed three sampling techniques and then evaluated the techniques. Ontario Research Foundation and BLP constructed the equipment and performed initial laboratory tests. All three team members then participated in the field tests with GLL installing the soil probes and ORF and BLP performing the sampling technique tests.

2. PROCEDURES

2.1 Background

The candidate soil gas sampling techniques suggested by ORF/BLP and alternative techniques suggested by the other contractors were discussed in a meeting of CMHC and ORF. It was decided that three techniques suggested by ORF/BLP with some modifications would be developed and field tested. Prior to this meeting, published literature on soil gas sampling obtained since the completion of the 1987 study was reviewed, in order to determine if new, relevant information was available. Various studies were reviewed, but nothing which would directly assist in the development of sampling techniques was found.

2.2 Sampling Equipment

As previously mentioned, three candidate basement soil gas sampling techniques were chosen for development and testing. The following outlines the construction and laboratory testing prior to field testing.

Floor Drain Sampling

In order to sample soil gases which might enter through basement floor drains and sump pits, rigid enclosures of various sizes were constructed. These enclosures would cover the floor drain opening plus an additional area to insure an adequate seal with the floor. This technique would rely on the natural pressure differentials across the basement envelope to inflate a thin-wall plastic sampling bag attached to the floor drain enclosure (Figure 1). Tests were conducted by BLP in the laboratory with the equipment to select an appropriate diameter tube to

connect the enclosure to the sampling bag. The ability and rate of inflation of the sampling bag was tested for various tube diameters and a tube of 38 mm (1.5 in.) diameter was chosen.

In order to measure the volume of soil gas contained in the inflated bag, a 23 litre (L) (5 gal.) container was calibrated. The inflated sampling bag would be sealed and inserted in the container and a disc placed on the bag to record the volume of gas in the bag.

Wall Tube Sampling

This technique involves drilling a small hole through the foundation, and inserting a 13 mm diameter aluminum tube through the foundation to the soil interface (Figure 2). Sampling may be conducted from the tube by two methods. A thin-wall plastic sampling bag may be attached to the tube in a manner similar to that for the floor drain sampling, or a sample may be withdrawn actively with a sampling pump. Two washers were placed on the outside of the tube to provide a tight fit in the foundation wall. Small critical flow orifices were inserted in the tube to provide a means of determining sampling flowrates. Automotive carburetor jets were used as orifices. These orifices were calibrated to obtain curves of flow versus pressure differential.

A 500 mL vacu-cylinder was used with a sampling pump to obtain a sample actively.

Wall Crack Enclosure Sampling

To sample wall or floor cracks, rigid enclosures were constructed which would cover a 240 mm (9.5 in.) diameter circular area surrounding the crack plus a plastic shroud which extended to a radius of 500 mm from the crack (Figure 3). The same 500 mL vacu- cylinder and sampling pump was used to obtain a sample actively.

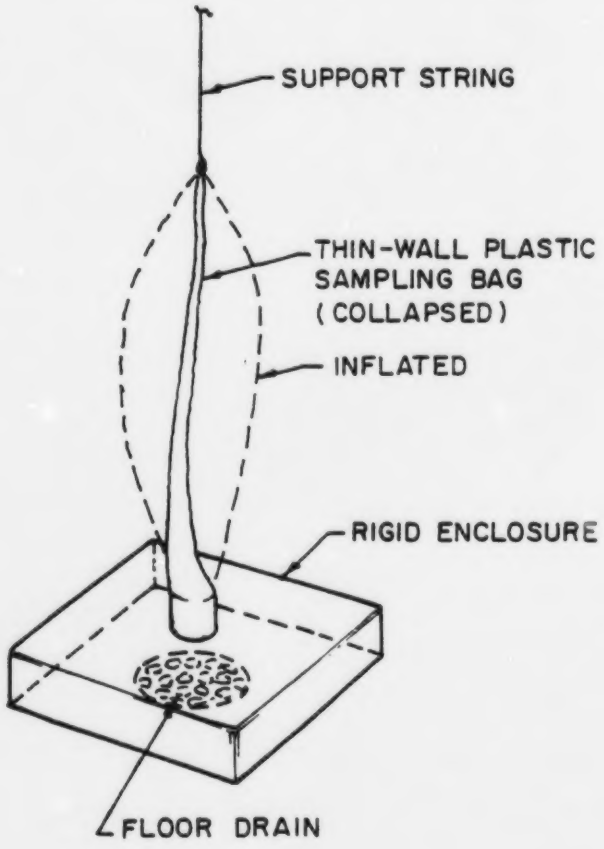


FIG. 1 FLOOR DRAIN SAMPLING TECHNIQUE

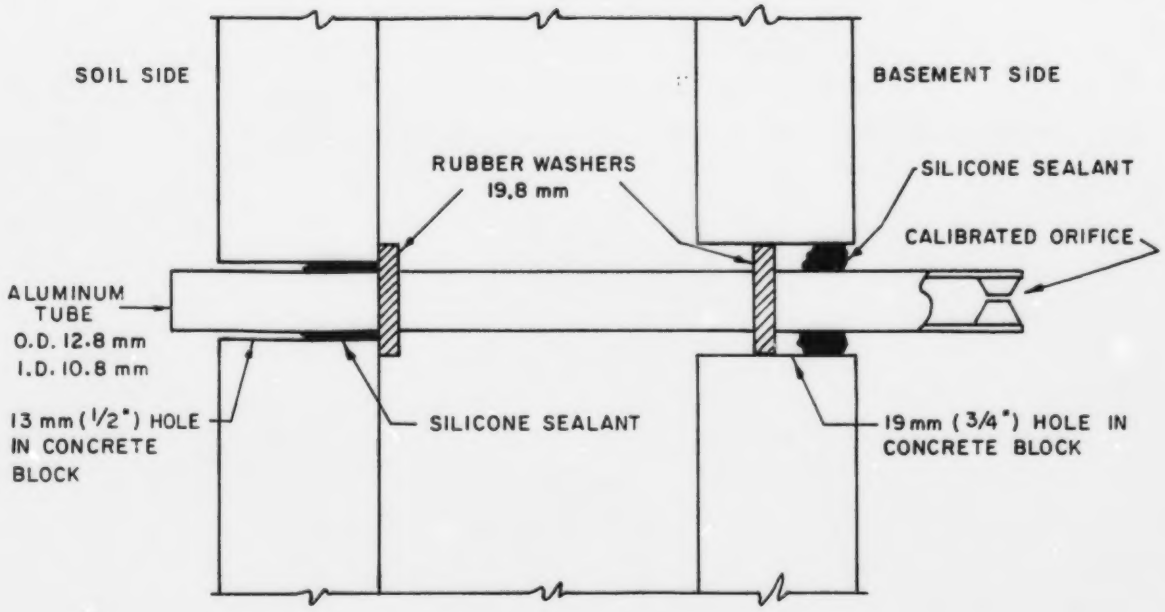


FIG. 2 WALL TUBE SAMPLING TECHNIQUE
(CONC. BLOCK CONSTRUCTION)

3. RESULTS

3.1 Field Sampling

The field sampling aspect of this study involved developmental testing of the soil gas sampling techniques in three houses. Two houses were selected in the Toronto area and one in the Ottawa area based on basement foundation type, access to soil gas entry points and cooperation of the homeowners. This progress report describes the field sampling in the three houses.

In order to evaluate whether the soil gas sample obtained by the sampling techniques is similar to the soil gas in-situ, a tracer gas, SF_6, was used. The tracer gas was injected into the soil adjacent to the foundation wall opposite the crack or wall tube entry points. Samples were then taken for SF_6 analysis from the soil and from the samples obtained with the candidate sampling techniques.

Soil Probes

Soil probes were used in this study to provide injection points for the tracer gas, to enable sampling of the soil gas in-situ adjacent to the foundation and to describe the soil conditions adjacent to the foundation.

Test holes were hand-augered to determine soil type and provide information on the water table location. The soil gas probes were those used in the previous soil gas study[1]. The probes consist of a 53.5 mm diameter thin-walled aluminum tube. The upper end was machined to facilitate the insertion of a sealed sampling head. Two 6 mm holes were drilled in the bottom 50 mm of the tube to create a well screen. The bottom of the tube was left open to allow soil gas entry. The sampling head was equipped with a rubber "O"-ring which was coated with teflon

grease to ensure a pressure seal. Two screws were installed above the ring to provide the necessary security. The head was equipped with a two-way valve and protector cap.

A 53.5 mm vibratory drill was used to advance a borehole at each monitor location. The soil samples recovered from the deepest hole at each site were logged to confirm soil types. Figure 4 illustrates a typical monitor installlation. The monitors were installed by pushing the tube down into the open hole so that the screen was at the desired depth. The borehole was initially extended 0.1 to 0.2 m past the proposed screen location. Thus, any soil dislodged during monitor construction would fall into this reservoir and not block the screen. Measurements wwere taken to ensure that the monitor was clear and any soil blockage was removed with a hand auger. A saturated bentonite seal was placed around each monitor at the ground surface to prevent the entry of ambient air.

A similar monitor location configuration was installed at each residence. Two monitors were placed, parallel to the foundation wall within the envelope of disturbed backfill soils, to serve as tracer gas injection points. A third monitor was placed between these and the foundation wall to serve as an intermediate sampling point. All three monitor screens were at a similar elevation to the in-house sampling point in the foundation wall. A fourth monitor was placed beyond the injection wells at a greater depth to serve as a ground water monitor.

First Test House

The first house in Toronto was a two-storey house with a basement of concrete block construction. Initial site inspection and testing with a smoke pencil identified wall cracks and a floor drain which both exhibited leakage of air into the basement below grade. Soil

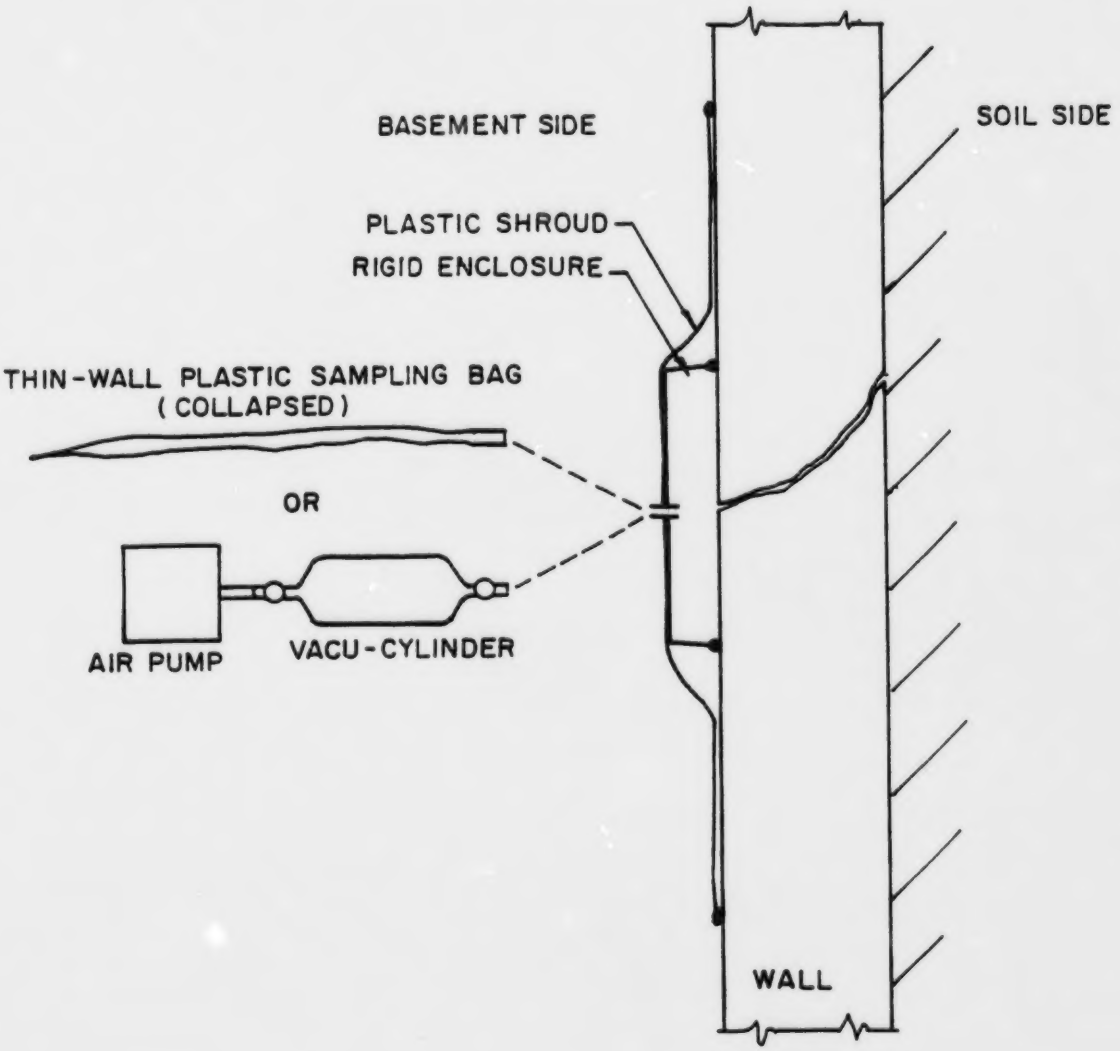
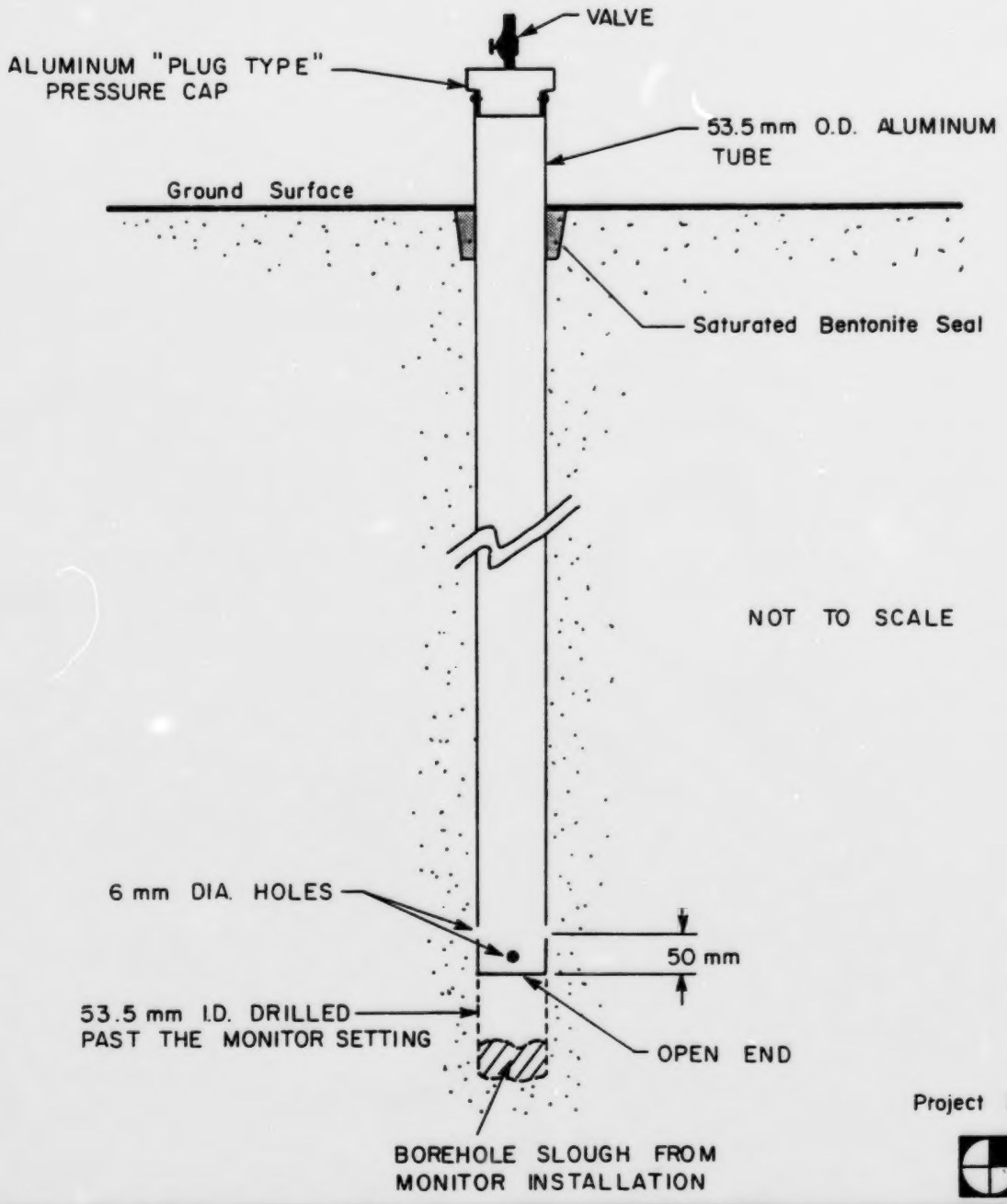


FIG. 3 WALL CRACK ENCLOSURE SAMPLING TECHNIQUE

Figure 4

TYPICAL MONITOR INSTALLATION



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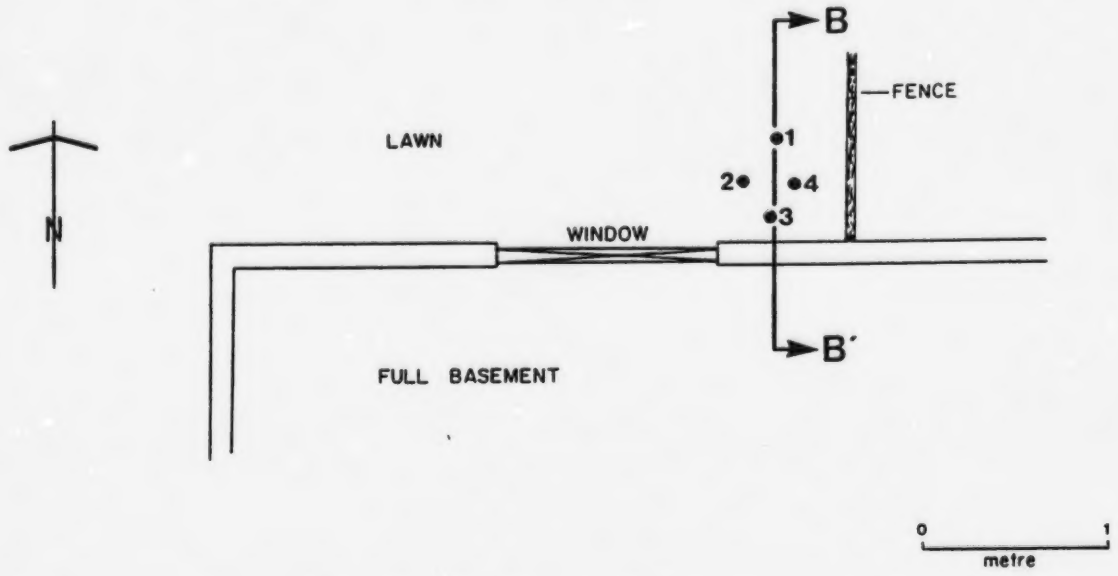
probes were installed in the soil adjacent to a wall crack in the north basement wall for the injection of SF_6 tracer gas and soil characterization (Figure 5). The soils within the disturbed soil envelope were clayey silt fills and represent the lower range of permeability.

The first technique tested was the wall crack enclosure method. The enclosure and shroud were sealed to the wall over the crack in the north wall with duct tape and silicone sealant. Approximately 20 litres of 0.1 percent SF_6 in air were injected into the soil. At 30 minutes after injection, soil gas was withdrawn from the wall crack enclosure at a rate of 15 L/min. into a continuous infrared analyzer to determine if sufficient SF_6 for detection had migrated to the sampling point. The analyzer recorded SF_6 of sufficient concentration to permit continuation of the tests.

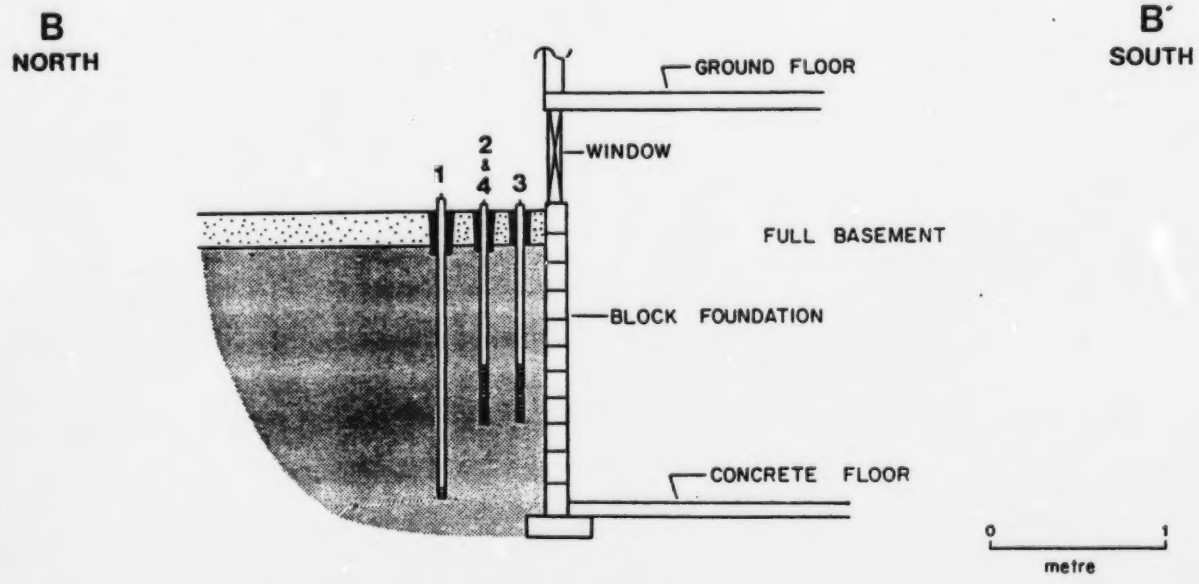
Two samples were then withdrawn from the wall crack enclosure into the vacu-cylinder and transferred to small vacu-tainers for shipment to the laboratory for analysis of SF_6. These samples were taken at approximately one hour after injection of SF_6 into the soil. Samples of SF_6 were then taken from three soil probes by the same procedure. The concentration of SF_6 in the two wall crack enclosure samples averaged 0.8 ppb and the soil probe samples averaged 2.5 ppb.

The wall crack enclosure was then removed from the north wall and a hole drilled in the same area for installation of a sampling tube. For installation in block wall construction, an inside hole of 19 mm (3/4 in.) was drilled into the centre cavity of the block. A 13 mm hole was then drilled in the outer wall of the block to the soil. A wooden dowel was then used to push soil away from the outer hole before insertion of the sampling tube. The sampling tube was then installed and sealed.

PLANVIEW



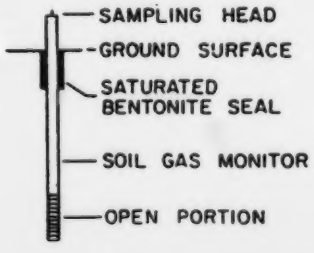
CROSS-SECTION



LEGEND

CLAYEY SILT TOPSOIL

CLAYEY SILT FILL



Cross Section B-B' And Planview

FIGURE 5

First Residence
Soil Gas Investigation

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A second injection of SF_6 into the soil was made and passive sampling from the tube started. After one hour, 1 litre of gas had entered the sampling bag. A sample of this was taken for SF_6 analysis and a concentration of 47 ppb was determined. Pressure differentials measured across the north wall at this location, recorded pressures higher than at other locations in the basement, 4 to 6 Pa. Samples for SF_6 were then taken actively from the tube with the pump and vacu-cylinder. These samples averaged 3.0 ppb SF_6. Samples taken from the probes at 110 minutes after injection averaged 15 ppb SF_6.

In addition to the crack adjacent to the soil probes in the north wall, tubes were also installed in the south wall below grade and in the floor. Pressure differentials at the tube installed in the south wall measured 1.5 to 2 Pa. After a sampling period of 1 hour, 8 litres of soil gas had entered the passive sampling bag. Pressure differential across the floor measured 1 to 2 Pa and a 13 litre sample was obtained in the passive sample bag after 40 minutes.

For the floor drain, an enclosure was placed over the drain and the passive sampling bag inflated to approximately 60 litres in 1.5 hours. The first bag was then removed and a second installed. This second bag inflated considerably faster, reaching approximately 50 litres in 5 minutes. After half an hour the second bag did not inflate further, even though pressure differentials of 1.5 to 2 Pa were still measured. When the bag is inflated beyond a certain point, the back pressure may be sufficient to prevent further inflation of the bag.

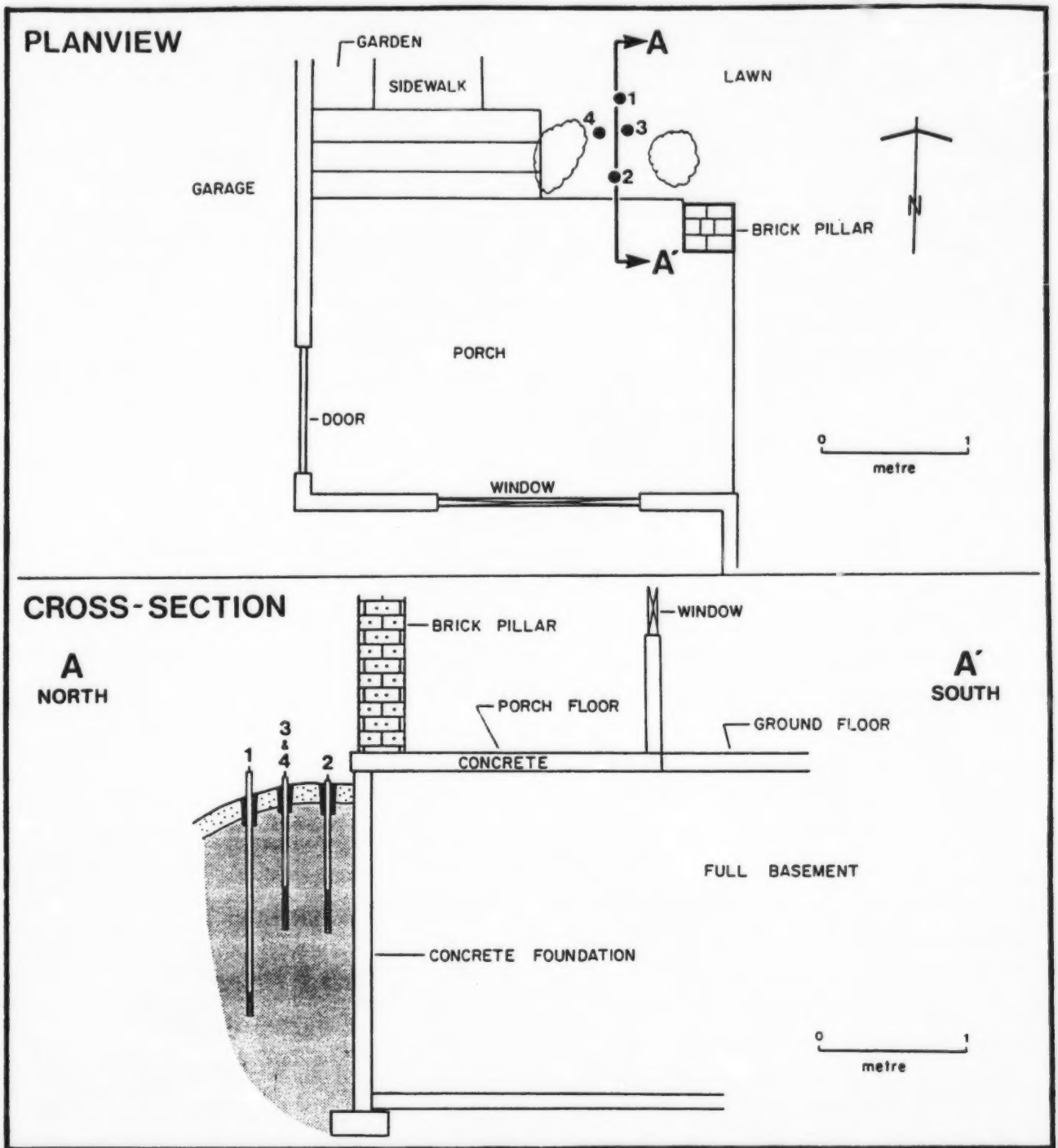
Active sampling was conducted from a soil probe and a wall tube before and after the drilling and installation of the sampling tube. This sampling was conducted to determine if the installation of the wall tubes could result in contamination of the soil gas. There was concern that disturbance of the exterior foundation coating might release

contaminants such as tars to the soil gas. Samples were obtained by means of a sampling pump and charcoal adsorption tubes for volatile organic compounds. The charcoal adsorption tubes were then analyzed by GC/FID and GC/MSD. No detectable peaks were measured in the probe sample prior to installation. Tube samples after installation had trace quantities of silicone which originated from the sealant used in the installation of the tubes.

Second Test House

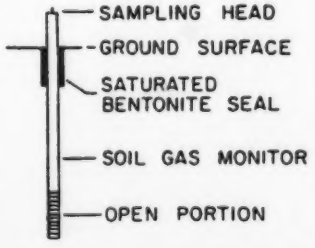
The second house in Toronto was two-storey with a basement of poured cement. Initial site inspection and testing with a smoke pencil identified a floor drain which exhibited in-leakage air. Soil probes were installed adjacent to a basement wall of a cold storage room where a wall tube would be installed (Figure 6). The soils within the soil envelope were silty fine sands and represent more permeable soils.

Two 13 mm holes were drilled in the concrete wall adjacent to the soil probes and sampling tubes inserted and sealed. One tube was for active sampling of SF_6 and volatile organics and the other tube for passive sampling with a thin-wall plastic bag. Approximately 30 L of 0.1 percent SF_6 was injected into the soil. After 30 minutes, two SF_6 samples were taken from the sampling tube using the vacu-cylinder and the sampling pump. The concentration in these two samples averaged 6.8 ppb. After an hour from injection, two SF_6 samples were taken from the soil probes. The concentration in these soil probe samples averaged 13 ppb. The passive sampling bag with a tube and orifice of 1.5 mm (0.06 in) inflated with 2.5 L in 132 minutes. A sample was taken from this bag for SF_6 analysis and the concentration was 6.3 ppb. The pressure differential across the wall at this point was 1 to 2 Pa. An ambient basement sample taken at 3 hours from injection had a concentration of 5.9 ppb.



LEGEND

- CLAYEY SILT TOPSOIL
- SILTY FINE SAND FILL



Cross Section A-A' And Planview

FIGURE 6

Second Residence
Soil Gas Investigation

For the floor drain, an enclosure was placed over the drain and six tests conducted. The inflation/sampling times and volumes were as follows:

Test	Test Duration	Volume Sampled
1	64 minutes	39 L
2	45 minutes	Bag full
3	14 minutes	65 L
4	4 minutes	30 L
5	200 seconds	18 L
6	200 seconds	28 L

When the sampling bag was removed from the floor drain an unpleasant sewage odour could be detected. A sample of this was transferred to a 10 ml vacu-tainer for analysis. Analysis of this 10 ml sample by GC/MSD did not show any detectable compounds. The total quantity of organic compounds contained in this 10 ml sample were insufficient to permit measurement by GC/MS.

Third Test House

The Ottawa test house was a two storey with a basement of concrete block construction. The block walls showed no visible signs of cracking, yet minor moisture leaching had occurred on a section of the north wall. The sump pit (0.3 m x 0.46 m) was located in the northeast corner of the basement floor. The soil probes were installed in the soil adjacent to the sump near the north basement wall (Figure 7). During installation of the soil probes, the soil was identified as clay-silt fills of low permeability. Probes #1 and #2 were installed to depth of 1.4 meters. Probe #3 was installed to 0.91 meter before hitting a solid object. Probe #4 was installed solely to determine the water table location.

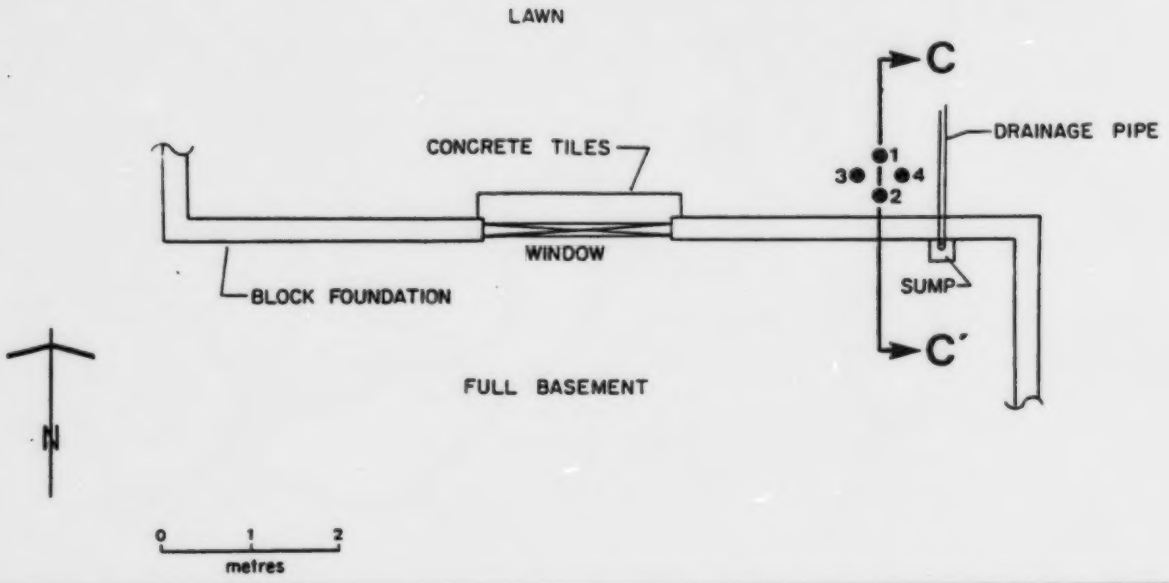
Two field tests were conducted at the third test house. To

enable monitoring of the sump pit during the first test, a two-piece enclosure was constructed that would fit around the two water pipes which connect to the sump pump in the pit (Figure 8). In addition to the collection of a sample with a passive sampling bag, a portable continuous radon daughter measurement instrument manufactured by Thomson Nielsen Electronics Ltd. was used in the testing of this sump pit. A portion of the enclosure was constructed of plexiglass so that the radon instrument could be placed in the enclosure and the instrument results output display read. The box was sealed to the floor with the radon instrument inside and the passive sampling bag attached to the top. Within 13 minutes, 22 litres of air had entered the sampling bag.

Subsequent sump pit sampling bags inflated at rates of 35 litres in 10 minutes and 24 litres in five minutes. A micro-manometer was hooked up to the sump enclosure and the three wall tubes at various times to determine the pressure differential. The sump enclosure recorded readings ranging from 1.0 to 1.75 Pa.

Wall sampling tubes were installed in three locations in the first test. A wall tube with a calibrated orifice of 1.5 mm (0.06 in) diameter was installed in the north wall near the sump pit and adjacent to the soil probes. A sample of three litres was obtained with this wall tube after 46 minutes. The pressure differential at this point was 1.0 to 1.5 Pa. The wall tube installed in the south wall also had a 1.5 mm orifice. Pressure differentials at this south wall tube exhibited short-term and long-term fluctuations. In the morning, short-term readings would range from 1.0 to 2.5 Pa. In the afternoon, the readings would fluctuate from 2.5 to 4.25 Pa. The cause of this increase from morning to afternoon and the higher pressure readings than at the other locations is not known at this time. The wall tube installed in the north wall west corner had no orifice jet and had pressure differentials ranging from 1.0 to 1.5 Pa.

PLANVIEW



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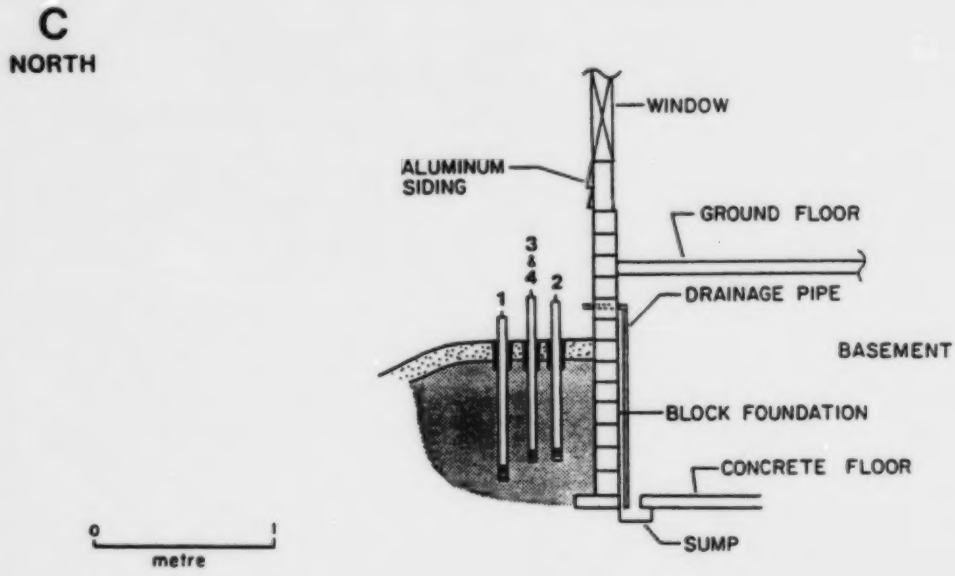
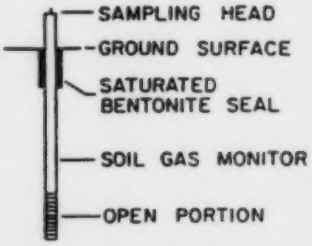


LEGEND

CLAYEY SILT TOPSOIL

CLAYEY SILT FILL

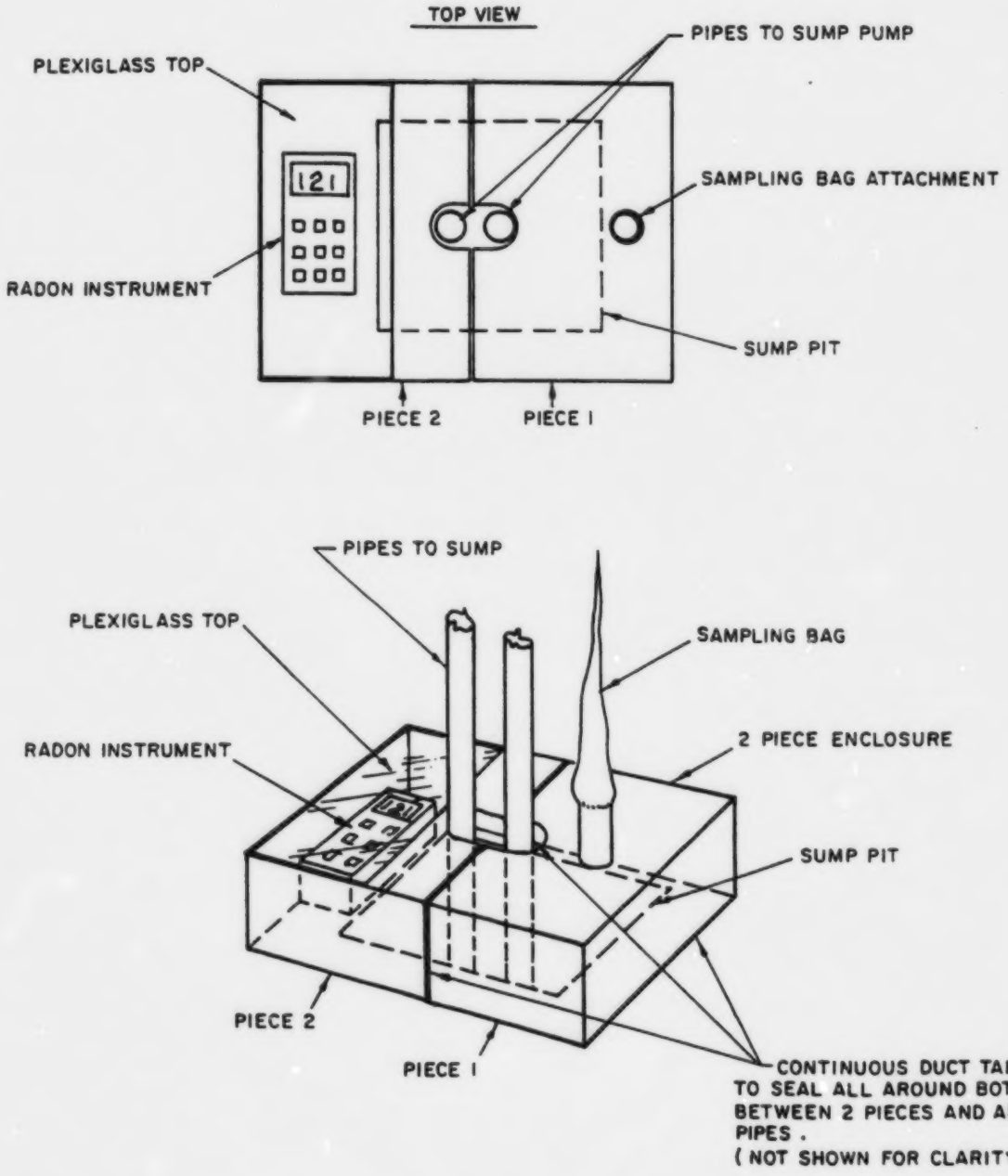


Cross Section C-C' And Planview

FIGURE 7

Third Residence Soil Gas Investigation

FIG. 8 SUMP PIT ENCLOSURE

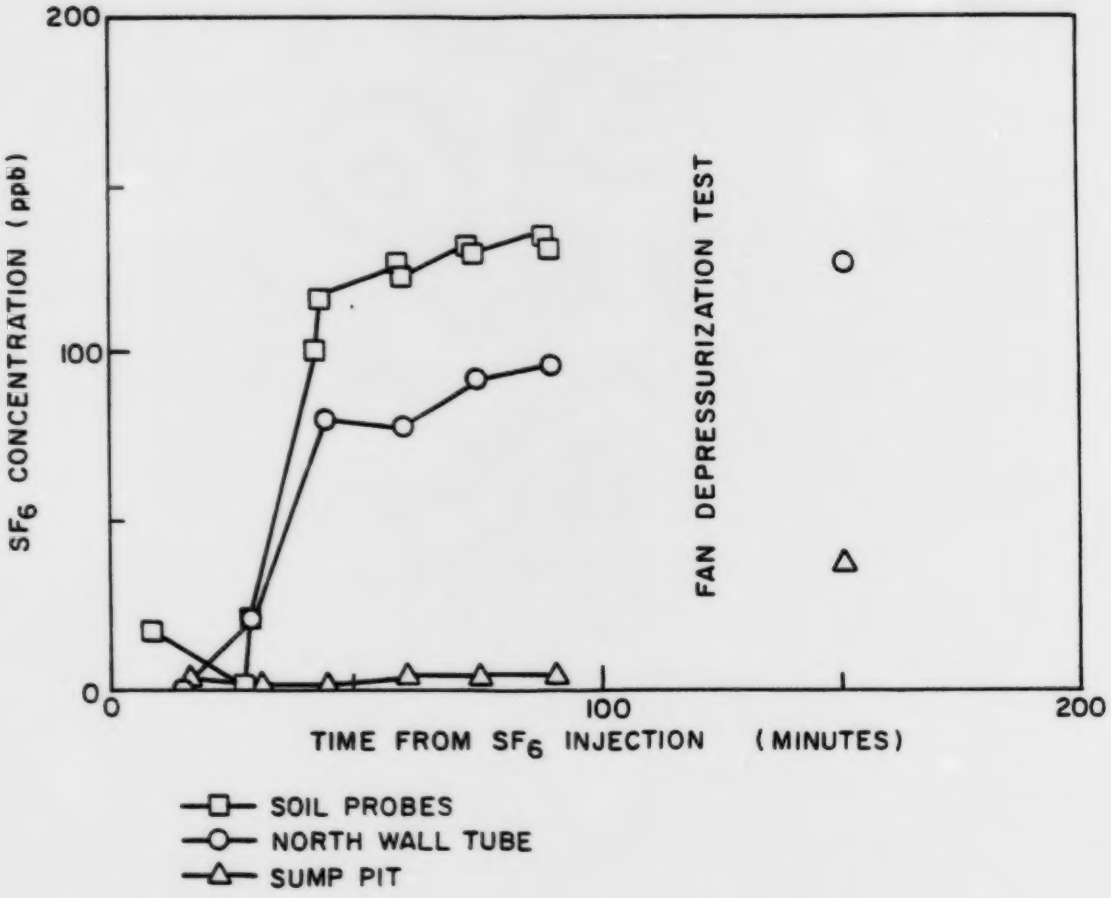


A tracer gas investigation was also conducted at this Ottawa house as part of the first test. Twenty (20) litres of 0.1% SF_6 were injected into the soil. Samples were taken every 15 minutes for 1.5 hours and then every one half hour for one hour at two soil locations, the north wall tube location, the sump pit and the ambient air of the basement. Two samples were also taken at the south wall and north-west corner wall tube locations. Concentrations of SF_6 versus time are presented in Figure 9 for the soil probes, the north wall tube location and the sump pit. After approximately 34 minutes from injection, the front of the SF_6 plume reached the soil probes and a concentration of 100 ppb was measured. At the same time, the sample taken from the north wall tube measured 80 ppb. After 100 minutes from injection, the increase in concentrations had slowed down with the probes measuring 135 ppb and the north wall location measuring 96 ppb. The SF_6 concentration in the sump remained low, less than 5 ppb, for the first 100 minutes. Five of the six ambient basement readings were less than 1 ppb, with one at 6 ppb. The 6 ppb may be the result of residue SF_6 contamination of the sampling syringe.

One hundred and thirty five minutes after SF_6 injection, a fan depressurization test was conducted on the house and indicated a forced air change of 4.3 ach at 50 Pa. After the fan test, SF_6 samples were then taken at the north wall tube, the sump pit, the south wall tube and the north-west corner wall tube. The north wall tube level increased to 126 ppb and the sump pit level to 38 ppb. The other wall tubes had levels similar to the basement ambient level, less than 1 ppb.

Throughout the on-site sampling of test one, the radon daughter instrument in the sump pit enclosure indicated 19 mWL. Assuming a 50 percent equilibrium between radon and radon daughters this is equivalent to 140 Bq/m^3. For one hour periods, enclosures were also placed over the three wall tubes and another radon instrument placed in these

FIG. 9 TRACER GAS RESULTS - OTTAWA HOUSE



enclosures. The wall tube radon levels were less than 2 mWL or <15 Bq/m^3.

The second test at this third house was conducted to evaluate the effect of sampling air from the center voids of a block wall foundation such as with the wall crack enclosure method. Since there were no cracks in the basement walls of this house a 13 mm diameter hole was drilled into the center void and a sampling tube with an orifice of 1.5 mm diameter inserted and sealed. A second similar tube was also inserted through the wall to the outer soil interface. This second tube would draw a sample both from the soil and from the center voids through two openings.

In a manner similar to the first test, SF_6 tracer gas was injected into the soil and sampled from these two tubes. A trend similar to that presented in Figure 9 was observed, but with lower concentrations. After approximately 50 minutes the concentrations of SF_6 from the two tubes reached levels which remained constant for the next two hours. The tube which sampled from the void only rose to 1.5 ppb. The tube which sampled both the void and the wall-soil interface rose to approximately 40 ppb.

From these results it can be concluded that considerable dilution of soil gas with ambient air can occur across a block wall foundation.

3.2 Discussion of Results

The results of the tracer gas injection and sampling tests for the first house in Toronto indicate that, for the wall crack enclosure sampling method, there was a small decrease in tracer gas concentrations

from the soil probes to the sample taken on the inside of the block wall. Measured concentrations of SF_6 decreased from 2 to 3 ppb in the soil to just less than 1 ppb, average of 0.8 ppb, for the wall crack enclosure samples. This difference is probably due to dilution of the tracer as it migrates through the soil into the basement. However, since these concentrations were low and only 4 samples were taken, further conclusions cannot be made.

For the second injection at this house, an integrated 1-hour passive sample from a wall tube measured a much higher concentration, 47 ppb. Active samples from this wall tube, 30 minutes after completion of the 1-hour passive sample, measured 2 to 4 ppb. The soil probe samples taken 20 minutes later measured 7 to 29 ppb, average of 13 ppb. It would appear that the majority of the SF_6 tracer gas may have passed through the wall into the passive sampling bag within the first hour after injection. The lower values would indicate that the SF_6 had dissipated after one hour. However, only 5 samples were taken and definitive conclusions cannot be made.

The soils in which the probes were installed for this first house were clayey silt fills which were also wet during sampling. These soils when wet are of low permeability and soil gas migration should be very slow and may have influenced this variability in the results.

During the tracer gas test at the second house, parallel passive and active wall tube samples were taken. The results indicate similar concentrations with both techniques. The passive sample had a concentration of 6.3 ppb and the average of the two active samples was 6.8 ppb. The concentration measured in the soil was 13 ppb. This decrease from the soil probes to the samples was probably a result of dilution through the soil.

For the tracer gas test at the third house in Ottawa, considerably more samples were taken in order to more accurately define the soil gas migration and basement entry behaviour. The active wall tube sampling, Figure 9, indicates that the tracer gas did migrate to the sample tube and would enter the basement with the soil gas. The difference in soil probe concentrations and sampling technique concentrations was probably due to the dilution through the soil in the short distance from the probe to the wall.

The tracer gas test at the third house to determine the potential degree of dilution across a block wall indicated that significant dilution can occur. In this instance, a dilution of approximately 50 times was measured.

The wall tube adjacent to the wet impermeable soils at the first house had pressure differentials of 4 to 6 Pa and a soil gas entry flowrate of 1 L/h. In the other wall tube locations in floors and walls adjacent to drier more permeable soils, the soil gas entry flowrates were greater, 3.9 to 19.5 L/h, for lower pressure differentials, 1 to 2 Pa.

The variability of the soil gas entry flowrates from the floor drains could not be explained by the differential pressures. The pressure differences across the floor drains were similar during the tests, 1 to 2 Pa, but the entry flowrates varied from 36 to 600 L/h. Further information on the design of the drain systems was not obtained to determine if it could be a factor.

A 10 mL sample of odourous soil gas from a floor drain was analyzed but was insufficient for analysis. The volume of soil gas sample required in order to provide sufficient sample for analysis depends on the constituent concentration in the soil gas. Currently, because insufficient data is available to characterize constituents in

typical soil gas, stipulation of a minimum sample size is difficult. However, the lower quantifiable detection limit for many volatile organic compounds (VOCs) by GC/MS is approximately 0.1 µg/sample. For a gas, samples are usually concentrated on solid adsorbents such as Tenax and then desorbed for GC/MS analysis. If a 10 L soil gas sample is collected and then transferred to a Tenax tube for eventual analysis, a lower quantifiable limit of 0.1 mg/m^3 is obtained for VOCs. Values of 0.1 mg/m^3 to 1.0 mg/m^3 VOCs are typical of indoor air. Therefore, soil gas samples of 1 to 10 litres should be sufficient for VOC analysis. Pesticides, herbicides and insecticides are analyzed by GC/EC which has a detection capability of less than GC/MS and, therefore, samples of 1 to 10 L should also be sufficient for analysis of these constituents.

4.0 CONCLUSIONS

Floor Drain Sampling

The floor drain and sump pit enclosure sampling techniques designed for this study were successfully used to obtain soil gas samples of greater than 10 L in time periods of one hour or less. In addition, the rate at which the sample was collected was used to determine the rate of entry of soil gas. The design was such that it could be easily constructed at low cost.

In the three houses studied, the soil gas entry rates through the floor drains were larger than through wall cracks or other openings.

Water Tube Sampling

The wall tube sampling technique when used in conjunction with

the passive bag or with an active sampling pump was also successful. Due to the slower rates of entry through the wall tubes in floors and walls, sampling times of greater than one hour may be required in order to obtain soil gas samples of 10 L. When a pump with a flowrate of 1 L/min is used, short-term samples can be obtained in 10 minutes. The rate at which the sample is collected in the passive bag can be used to determine the soil gas rate of entry.

Wall Crack Enclosure Sampling

Conclusive results were not obtained to determine that this technique was successful in obtaining samples of undiluted soil gas. The one evaluation test indicated that an undiluted sample was obtained. However, because of the limited data of this test, a firm conclusion cannot be made. The test to determine potential dilution across a block wall indicated that a dilution of soil gas of 50 times can occur. Because this technique would sample from the inner surface of a foundation wall, it is concluded that it may not be successful in obtaining an undiluted soil gas sample from a block wall foundation.

Analysis of Soil Gas Samples

Based on the capability of organic compound laboratory analytical equipment such as GC/MS or GC/FID, a minimum soil gas sample of 10 L is recommended. A sample of this size can be obtained with these sampling techniques. If the sample is to be obtained actively, it can be collected directly in a solid adsorbent sampling tube. If the sample is collected in a passive bag, the gas sample must first be transferred to a solid adsorbent sampling tube prior to analysis.

REFERENCES

1. Ontario Research Foundation and Gartner Lee Associates Ltd., Development and Evaluation of Soil Gas Sampling Techniques for Canada Mortgage and Housing Corp., August 1987.